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VOLUME 8 NUMBER 12

DECEMBER, 1918

Phytopathology

Official Organ of the

American Phytopathological Society

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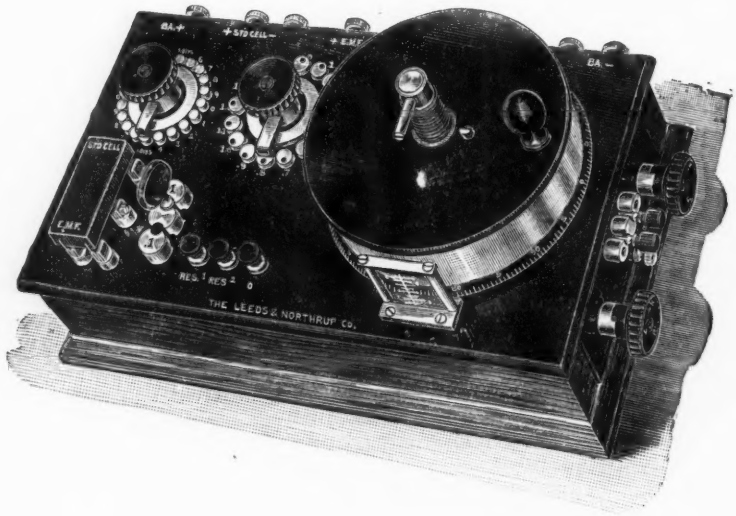

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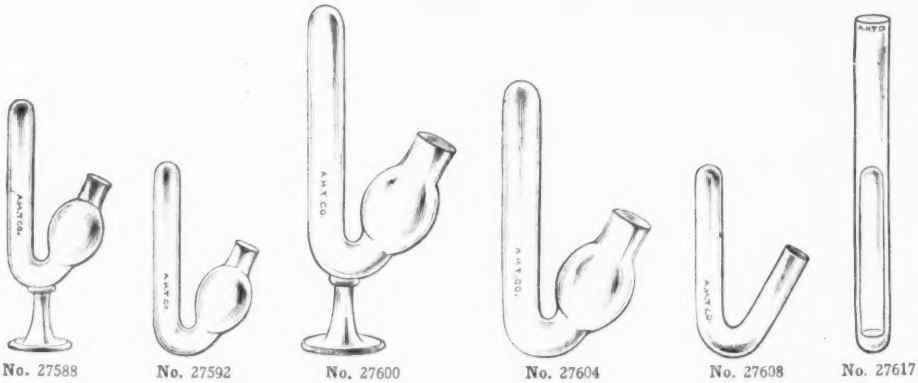

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PHYTOPATHOLOGY

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VARIETAL SUSCEPTIBILITY OF BEANS TO STRAINS OF COLLETOTRICHUM LINDEMUTHIANUM (SACC. & MAGN.) B. & C.

MORTIER F. BARRUS

During recent years much time and effort have been expended by scientists in selecting and breeding plants for the purpose of obtaining varieties or strains of varieties resistant to disease and in endeavoring to determine the factors responsible for resistance. It can be said, without fear of contradiction, that considerable progress has been made in securing disease-resistant plants. It is not necessary here to enumerate them, for they are known to all who will give this paper attention, nor is information altogether lacking concerning the causes of disease resistance.[1] We have come to recognize that probably no one factor is responsible in every case but that there are many diverse factors, each one of which or a combination of some of them, occurring in a certain individual and its progeny, or in certain varieties or species, enables such plants to resist a particular disease. These factors may be transmitted to other varieties of the species by breeding, so that plants having good qualities otherwise but susceptible to a serious disease may also take on the desirable character of resistance to this disease. The particular factors imparting the character of resistance to a certain disease of a plant do not seem, in most instances at least, to be able to impart resistance to other diseases of that plant. Much additional information is needed regarding individuals, varieties, and species that are resistant to disease, in order that abundant material may be available for future work in breeding and selecting and for further studies of causes of resistance.

Pathologists generally now recognize the necessity in securing plants resistant to disease of selecting those individuals only that have been

[1] Butler, E. J. Immunity and disease in plants. Agricultural Journal of India. Special Indian Science Congress Number, 1918: 10-28.

exposed to this disease under conditions very favorable for infection, either those individuals surviving a natural epiphytotic or an artificial inoculation. During and since 1910 the writer has endeavored to secure beans resistant to anthracnose.[2] As epithytotics of this disease do not occur during dry summer seasons, artificial inoculations were made both to varieties growing in the greenhouse and in the field. Interesting data were secured regarding differences in the causal organism, *Colle'otrichum lindemuthianum*, obtained from different sources. Varieties resistant to repeated inoculations made with a culture obtained in one locality became seriously affected when inoculated with a culture obtained in another locality and, curiously enough, some of the varieties that had shown excellent infection from inoculations made with the first culture were very resistant to the organism obtained from the second locality. The results obtained from these and from inoculations made with cultures obtained from still other places were published several years ago.[3] From inoculations made then there appeared to be at least two distinct strains of the organism not appreciably different from each other morphologically or in culture reactions and only to be distinguished by inoculation on certain varieties of beans. No variety had been found that is resistant to both these strains.

Since that time a great many inoculations have been made with additional varieties, species, and genera of beans and with cultures obtained from widely separated sources. The work has been done as time could be spared from other duties and has necessarily extended over a considerable period. It seems wise to delay no longer the publication of results secured, as the information will be of use to others who may wish to work upon some phase of the problem.

Seed of the varieties used was obtained from time to time from seedsmen in different parts of the country, many of whom sent the varieties requested with their compliments. Jarvis'[4] description of varieties was consulted and his arrangement of synonyms given consideration in ordering varieties. For the most part the seed obtained was true to name and produced but few sports. As far as possible each order for a certain variety was placed with the same seedsman year after year. Occasionally seed was obtained affected with anthracnose. These were sorted

[2] The work reported in this paper was conducted in the laboratories, greenhouses, and gardens of the Department of Plant Pathology, at Cornell University while the writer was connected with the College of Agriculture at that institution.

[3] Barrus, Mortier F. Variation of varieties of beans in their susceptibility to anthracnose. Phytopath. **1**: 190–195, pl. 29, 1911.

[4] Jarvis, C. D. American Varieties of Beans. N. Y. (Cornell) Agr. Expt. Sta. Bul. 260: 149–255, pls. 1–15. 1908.

out as well as the eye could detect. However, the type of infection on a seedling produced by the organism wintering in the seed was easily distinguished from that produced by an artificial inoculation. It would have been better before beginning inoculation experiments of this kind, to have grown each variety two years in separated plats, rejecting those showing variation from the true type and those becoming affected by anthracnose. But, as a whole, the results clearly indicate that most of the varieties were rather constant in the character of their reaction to strains of organism used, so that we must conclude that the varieties in such cases were pure. The lack of absolute certainty regarding their purity offers a favorable explanation for the irregular behavior of certain other varieties when inoculated at different times.

The sources of cultures used in these experiments and in experiments reported in the writer's previous publications on this subject are given herewith:

A. Cultured from a spot on a seed at Oneida, N. Y. September, 1909

B. Obtained from Dr. Charles Gregory, who cultured it from a spot on a seed grown on Cornell University grounds, Ithaca, N. Y. November 22, 1910.

D. Cultured from a lesion on a stem of a Detroit wax bean seedling grown in greenhouse at Cornell University. Source of infection unknown. March 31, 1911.

E. Cultured from an acervulus on a dry bean pod kept in attic over winter. April 8, 1911.

F. Cultured from a spot on a wax bean pod obtained at an Ithaca, N. Y., market. June, 1913.

G. Cultured from a spot on a bean seed; variety and source unknown. December, 1917.

H. Cultured from a spot on a seed obtained from Joseph Harris Company, Coldwater, N. Y. June 12, 1911.

J. Cultured from a spot on a Longfellow bean seed obtained from Vaughan's Seed Store, Chicago. June 12, 1911.

K. Culture sent by Prof. H. H. Whetzel from Heidelberg, Germany. April, 1914.

N. Cultured from a spot on a seed; variety and source unknown. February, 1912.

P. Cultured from a spot on seed obtained from Dr. C. W. Edgerton, Baton Rouge, La. October, 1912.

Q. Cultured from a spot on a pea bean seed of some variety obtained from Columbia County, N. Y. October 25, 1917.

R. Cultured from a spot on a White Kidney bean seed obtained from Schenectady County, N. Y. April, 1918.

S. Cultured from a spot on a Navy Pea bean seed obtained from Spencer, N. Y. April, 1918.

X. Cultured from a spot on a seed; variety and source unknown March, 1912.

During the first part of this work, twenty-six separate inoculations were made on one hundred and thirty-seven varieties besides numerous other inoculations made on several of these varieties to which special study was given. Thirteen of these inoculations were made on seedlings in the greenhouse except in two cases which were made on seedlings out-of-doors; the remainder were made on potted plants growing in plats in the disease garden. In the greenhouse, the seed was usually planted in benches in rows 4.5 feet long, four varieties to a row, and twenty-six seeds in four hills to a variety, the rows being 6 inches apart. Good bench soil was used at first but later screened coconut fiber was used instead as it is easier to handle and its mechanical condition is not materially affected by steam sterilization. The plants were inoculated as soon as all or nearly all that would come up had appeared.

Stock cultures of the various strains of the fungus were kept on potato agar in a refrigerator but transfers for spore production were made to bean plugs in test tubes kept at about 21°C. under which conditions spores were very abundantly produced in about a week if the culture was in good spore-producing condition. The spores from a sufficient number of these bean plugs were removed by placing the bean pods in tap, rain, or distilled water, and gently rubbing them with the fingers. The suspension obtained was then strained through cheese cloth and atomized on the plants. All stems, leaves, and petioles were well wetted on all sides with the suspension. Usually the soil was saturated with water before inoculating the vines. The plat of beans was then covered with paraffined cloth tacked over a frame work. The inoculations were made during the afternoon or evening and the covering left on for about forty-eight hours. An effort was made to keep the temperature during incubation period, especially during the first two days, at 68°F. or below. Lesions began to appear on stems of susceptible plants in about four and a half days. In ten days the condition of the plants was most favorable for obtaining data and they were taken at this time when possible. Afterwards, the plants were pulled up, the soil steam-sterilized and made ready for another planting. It requires about a month to secure infection data from one series.

Plantings in the field were made in various ways. Sufficiently reliable data were secured by planting in a plat all of the varieties used, and by having as many plats as there were strains of the fungus to be applied. About twenty-five hills of each variety were planted in each plat. The

plats were separated from each other by several rows of corn which when 4 to 6 feet high made an effective barrier to the passage of mist containing spores as it came from the sprayer. The spores were cultured as described earlier but the suspension was sprayed on with a hand-sprayer which utilizes a quart fruit jar for a container. Spores of the several strains were prepared each in a separate jar, the sprayer being disinfected with formaldehyde solution between the application of each strain. The sprayer was held close to the plant in order to apply the suspension to the pods and to prevent it from floating away to other plats. The beans were inoculated when they contained an abundance of young pods. With so many varieties used it was necessary to make applications at different times to each plat in order to inoculate all varieties at a favorable period in their development. The weather also was considered and, when possible, the inoculations were made during or preceding rainy periods. Data were secured from these inoculations two or three weeks after they were made.

There were greater chances for error in the field than in the greenhouse inoculations. Such errors occurred without doubt, but it was surprising to find how regular was the recurrence of conditions in which the pods and vines of one variety would be free from infection whereas those of a neighboring variety would be severely diseased.

It was necessary in recording these data to designate the degree of infection resulting from the inoculations. A representation of the number of lesions does not indicate the degree of susceptibility of the plant to the disease because a single lesion on the stem may be so extensive as to cause the death of a seedling while a highly resistant plant may become extensively specked with very small lesions that cause little if any injury. Six degrees of suceptibility were established into which any bean plant affected with anthracnose can be conveniently classed. The data given should not be interpreted too strictly in respect to this because it can be readily understood that conditions varied somewhat in all these experiments and, too, one's decision is inclined to vary in the course of eight years. Especially will this variation occur when there are all gradations between the various degrees established. In some instances there may be no actual difference in the susceptibility between plants classed in one degree from individuals placed in the class above as more greatly affected or, more rarely, in the class below. The descriptions given refer to seedlings and to immature pods of older plants.

Description of degree of susceptibility of beans to anthracnose as used in text.

Excellent (E). Plate IA. Seedling usually dies. The lesions are deep and usually numerous especially on epicotyl and parts above. Pods become much spotted with deep lesions.

Good (G). Plate IB. Seedling usually survives. Lesions are numerous on epicotyl, petioles, veins, and pods, and may be deep. Pods usually mature most of their seed.

Fair (F). Plate IC. Seedling recovers from infections. Epicotyl and stem above may have many lesions but they are not usually deep or extensive. Pods may show numerous lesions but seed rarely becomes affected.

Slight (S). Plate ID. Development of seedling apparently unaffected by the disease. The plant may show numerous lesions but they are small in extent and in depth although spores may be produced in them. Such lesions often appear along ridges of stem and petioles and more rarely elsewhere. The pit of the lesion extends crosswise about 1 mm. and lengthwise about 1–3 mm. with the reddish border extending farther. Sometimes there are many brown specks also present. Small lesions may be numerous on the pods but the fungus does not penetrate to the seed.

Very Slight (v.S.). Plate IE. Lesions are black and fairly definite even though small. No spores produced.

None (N.) Plate IF. No indication of infection whatever. Also, cases in which fine brown specks are present over the surface of stems, petioles, or veins but no blackening or extension of these spots. They represent a condition in which the germ tube has penetrated the epidermal cells but was unable to proceed farther.

Seventy of the 137 varieties thoroughly tested during the first part of the work proved to be quite susceptible to all of the strains of the organism tried on them, with the few exceptions noted. The accession number of these varieties is given in a group below. The other varieties exhibited such interesting variations in their susceptibility that they are indicated in table 1 in a summarized form. Most of the varieties listed in the table were given seven separate inoculations with culture A, four with culture B, two with E, four with F, two with H, two with J, two with N, one with P, and two with X. One inoculation was made with D on twelve of these varieties.

The accession numbers were given consecutively to the varieties listed by Jarvis.[5] Each additional variety obtained was given a number, regardless of its classification. An index of varieties with their accession numbers is appended to this paper.

It is impossible in such a condensed table to indicate all the variations in results that occurred. When a single symbol is used it represents a condition in which all or nearly all of the plants in all of the inoculations

[5] Loc. cit.

TABLE 1

Results of inoculations with several cultures of Colletotrichum lindemuthianum, from diverse sources, upon certain varieties of beans grown in field or greenhouse

VARIETY NUMBER	CULTURE									
	A	B	D	E	F	H	J	N	P	X
6	E	N		N	(N. F. G. E)	F	F-E	E		E
9	N	E	E	E	F-E	F-E	N	E	E	N
12	S-E	E		F-G	N-E	G	N-F	E	E	N-E
16	S-E	N-E		N-F	N-E	N-E	N-F	F-E	S-E	F-E
17	S-E	F-E		N-S	N-S	N-G	F	F-E	F-E	F-E
20	N	E	E	G-E	E	F-G		E	E	
21	S	E		E	E		N-F	E	E	N
23	F-E	S-G		S-F	N-G	N-F	N-F	N-E	E	G-E
25	E	S-N		S-N	S-N	S-F	E	N-E	F	E
35	S-E	E		E	E		N-F	E	E	N-E
37	F-E	F-E		F-G	N-E	S-E	S-G	S-G	N-G	F-E
43	N-E	F-E		F-G	S-E	G-E	S-E	E	F-G	S-E
46	N-S	G-E	G-E	F-E	F-E	N	F-G	F-E	G	N
49	E	N-S		N	N-F	N-S	F-G	S-G	F	E
52	N-G	N-G		N-G	N-E	F-G	N-S	S-E	F-E	N-G
53	N	E	E	G	G-E	G	N	G		S
56	E	N		N	N-F	N	G-E	S-F	N-S	E
59	G-E	S-N		N	N	S	N-E	N	N	E
60	S-G	G-E		G-E	F-E	G	F-G	E	S-E	N-S
61	N-E	N		N	S-N	N	N-E	N-G	N-F	S-N
62	G-E	E		E	N	N				
69	E	N-F		N-F	S-E		G	F-E	N-S	E
70	F-E	S-G		N-S	S-E	S	G	S-G	S-G	G-E
74	N-G	N-E		G	G-E	F-G	N	G-E	N-E	N-F
76	G-E	N		N	N-F	N	F-E	N-F	N-S	G-E
79	S-N	G-E		G	G-E	G	S-N	F-E	E	S-N
83	E	S	N	N-S	N-G	N-F	F-G	N-G	S-F	E
85	F-E	S-G		G	N-G	F-G	N-S	F-G	S-G	N-S
88	N	E	G-E	G-E	G-E	G-E	N	E	G-E	N-F
89	N-E	N-E		N-F	G-E	S-G	N-G	G-E	G-E	G
95	E	N		N	S-E	S-F	G-E	S-G	E	E
98	G-E	N		N	N	N	F-G	N	N	F-E
100	F-E	G		N	S-F	S	G	S		F
101	N-E	N-E	F-E	S-F	N-F	S	N-G	N-F	N-F	N-G
102	F-E	F-G		S-F	F	N				
105	N-F	E		E	E		N	G-E	E	N-F
106	N-S	G-E	F-E	G	E	E	N	G-E	E	N-S
109	N-S	E	E	F-E	E		N-S	E	E	N-F
110	N-S	G-E		G	G-E	F-E	N-S	G		N-F
117	N-S				E					
120	N-S	E		E	E		N	G-E	E	N-S
123	G-E	N-G		N-S	N-F	G	N-G	G-E	G-E	E
124	N-S	E		E	G-E		N	E	E	N-S

TABLE 1—*Continued*

VARIETY NUMBER	CULTURE									
	A	B	D	E	F	H	J	N	P	X
125	E	N-S		N	N-F	S	N-E	N-S	S-F	E
127	N-S	E		E	E	G-E	N	E	E	S-F
129	N-F	N-E		N	N-E	N	N-E	N-G	S	F-E
130	E	N			N-S		E			E
132	N-S	E		G	E		N	G-E		S
133	N-E	N-E		N	N	N-F	G-E	N-F	N-S	E
134	E	N			N-S	N-S	G-E	N-F	N-S	E
135	N-S	F-E		N	N-G		N	F-E	G	N
137	E	N-F			S-F	N-S	N-E	S-F		E
138	G-E	N-S		S	N-F	N	G	S-E		E
139	N-G	N-G		G	S-E		N-F	N	G	N-F
140	E	N-G		N	N		G-E	N-S	N-S	G-E
142	N-E	N-E			F	S-G	N-S			N-G
144	E	N		S	N-S	N	E	N-F	N	E
145	S-E	N-E		E	N-E	G	N-F	N-E		S-G
146	E	N-F			S-G	N-F	G-E	N-F	N-S	E
147	E	N-F			N-F	S	F-E	S-F	S-N	G-E
148	G-E	N			N-F	N-S	N-E	N-G	N-S	G-E
149	E	F-E		S	N-G	S	G-E	S-G	N	E
153	S-N	G-E		G	E		N	S-E	E	N-G
199	S-G	F		S-F	F		N	G	S-F	
232	N-S	N-F		F	N-S	F-G	N	S-F		N-S
206	N-E	E		G-E	G-E	G-E	N-S	F-G	E	N-G
213	N-S	E	E	F-E	G-E	S-G	N	E		N
214	E	N-S		N	N	N	N-E	N-S	N	G-E
88A	S	N-S			N-F					

became affected to the extent indicated by it. Not infrequently one to several plants of a variety inoculated would show no infection while all the others gave excellent infection. If such a result showed up in several inoculations it is represented in the table as N-E; if it showed up in only one or two inoculations all the others giving uniformly excellent infection, the situation is indicated by E. A seed or two may have germinated late and the plant appeared above ground after the inoculation was made. In such a case they would be unlikely to show infection when the data were taken. Usually this was guarded against by counting the plants of each variety when inoculations were made. If all the plants of a variety showed no infection at one inoculation but excellent infection at the others the result is recorded as N-E when it was not known that infection failed to take place because of conditions, other than resistance of the variety. This situation should be given consideration in studying these data.

A careful scrutiny of these results reveals that a considerable number of the varieties uniformly exhibit a marked resistance to certain strains and susceptibility to others, and that among the remainder of the varieties some exhibit irregularities in behavior toward inoculation with these strains, while others indicate a resistance to all or nearly all. It is not unlikely that further trials with those varieties exhibiting these irregularities would place most of them in the class of those showing susceptibility to all strains, and the remainder would be assigned to the other classes. Cross-pollination occasionally occurs with beans grown out-of-doors and some of the varieties showing these irregularities may be those in which such crossing has occurred with their parents.

If consideration be given to the effect of inoculations with culture A and culture B on those varieties showing resistance to one and susceptibility to the other, it can be seen that earlier results[6] are confirmed in that those varieties which are susceptible to A are resistant to B and vice versa. Their response to inoculation with the other cultures reveals that these others produce results with few exceptions similar to those secured with either A or B. This is clearly brought out in table 2, in which fair infection is regarded as middle ground, less susceptible than fair as resistance, and more susceptible as susceptibility.

This remarkable behavior of certain varieties to inoculations with various cultures of the pathogene is more clearly shown in plates II, III and IV. Two varieties were planted somewhat apart from each other in each of two pots. Those in one pot were inoculated with one strain of the pathogene and those in the other pot with another strain. Conditions for infection were equally favorable in all cases. Yet, what a marked difference there is in the susceptibility of the two varieties in each pot to the strain with which they were inoculated, and what a turnabout in their response to an inoculation with a different strain. There is not only a biological difference in these strains but also in the varieties of beans themselves, apart from the difference in varietal characters. One need not require further evidence to recognize that the resistance of beans to anthracnose is not due to morphological characters of the host which make impossible the penetration of the germ tube, but rather it suggests that it is due to the physiological or chemical activities of the cell plasm.

The results indicated by the table clearly show that we must regard each of these several cultures as similar either to A or to B and that we have been concerned here with only two strains of the pathogene. As the word "strain" has been used in this and in previously published

[6] Barrus, loc. cit.

TABLE 2

Susceptibility (+) and resistance (−) of varieties to various cultures of Colletotrichum lindemuthianum

VARIETY NUMBER	A	J	X	B	D	E	F	H	N	P
6	+	+	+	−		−	+−	F	+	
9	−	−	−	+	+	+	+	+	+	+
20	−			+	+	+	+	+	+	+
21	−	−	−	+		+	+		+	+
25	+	+	+	−		−	−	−	+−	F
46	−	−	−	+	+	+	+−	−	+	+
49	+	+	+	−		−	−	−	+−	F
53	−	−	−	+	+	+	+	+	+	
56	+	+	+	−		−	−	−	−	−
59	+	+−	+	−		−	−	−	−	−
69	+	+	+	−		−	+−		+	−
70	+	+	+	+−		−	+−	−	+−	+−
76	+	+	+	−		−	−	−	−	−
79	−	−	−	+		+	+	+	+	+
83	+	+	+	−	−	−	+−	−	+−	−
85	+	−	−	+−		+	+−	+	+	+−
88	−	−	−	+	+	+	+	+	+	+
95	+	+	+	−		−	+−	−	+−	−
98	+	+	+	−		−	−	−	−	−
105	−	−	−	+		+	+		+	+
106	−	−	−	+	+	+	+	+	+	+
109	−	−	−	+	+	+	+		+	+
110	−	−	−	+		+	+	+	+	
117	−						+			
120	−	−	−	+		+	+		+	+
124	−	−	−	+		+	+		+	+
125	+	+−	+	−		−	−	−	−	−
127	−	−	−	+		+	+	+	+	+
130	+	+	+	−			−			
132	−	−	−	+		+	+		+	
133	+−	+	+	+−		−	−	−	−	−
134	+	+	+	−			−	−	−	−
135	−	−	−	+		−	+−		−	+
137	+	+−	+	−			−	−	−	
138	+	+	+	−		−	−	−	+−	
140	+	+	+	+−		−	−		−	−
144	+	+	+	−		−	−	−	−	−
146	+	+	+	−			+−	−	−	−
147	+	+	+	−			−	−	−	−
148	+	+−	+	−			−	−	+−	−
149	+	+	+	+		−	+−	−	−	−
153	−	−	+−	+		+	+		+−	+
213	−	−	−	+	+	+	+	+−	+	
214	+	+	+	−		−	−	−	−	−

articles [3, 7, 8, 9] in connection with Roman letters to designate certain cultures obtained from various sources, it will be less confusing in referring to the two strains embodying the others to use some other designation. Therefore the term "strain alpha" (α) will be used to refer to cultures to which the Ab (see below) group of varieties is resistant and the term "strain beta" (β) to refer to cultures to which the aB group of varieties is resistant. According to this terminology, cultures or strains called heretofore A, J, and X belong to strain alpha and those called B, D, E, F, H, N, and P belong to strain beta. The exceptions noted in the case of a few varieties may be readily explained in several ways, so that consideration need not be given to them here.

It is possible from the data at hand to classify all the varieties into five groups, as follows:

ab group—Varieties susceptible to both strain α and strain β; namely,—3, 4, 5, 7, 8, 10, 11, 13, 15*, 18*, 19, 22*, 24*, 26, 28, 29, 30, 31, 33, 34, 36*, 38, 39, 40, 41, 44, 45, 47, 48*, 50, 51, 54, 55, 57, 63, 64, 65, 66*, 67, 68, 71, 72, 75, 78, 80, 82, 84, 90, 92, 93, 94, 96, 97, 103, 107, 114, 116*, 118, 121, 122, 126, 128, 141, 143, 150, 200, 203, 204, 207, and 212.

aB group—Varieties susceptible to strain α but resistant to strain β; namely,—6, 25, 49, 56, 59, 76, 83, 98, 125, 130, 133, 134, 137, 138, 140, 144, 146, 147, 148, 149, 214, and with few exceptions 69, 70, and 95.

Ab group—Varieties susceptible to strain β but resistant to strain α; namely,—9, 20, 21, 46, 53, 79, 88, 105, 106, 109, 110, 117, 120, 124, 127, 132, 153, 213, and with few exceptions 85 and 135.

AB group—Varieties showing some resistance to both strains; namely,—61, 101, 129, 139, 142, 199, 202, and 88a.

Further trials have disqualified 142, 199, and 202 from a place in this group.

Miscellaneous group—Varieties showing irregularities in their susceptibility to strains α and β; namely,—12, 16, 17, 23, 35, 37, 43, 52, 60, 62, 74, 89, 100, 102, 123, 145, and 206.

Since the previous work was done, cultures of *Colletotrichum lindemuthianum* have been obtained from time to time from various sources (see pp. 591 and 592) and five of these were tested to determine whether they

[7] Barrus, Mortier F. An anthracnose-resistant Red Kidney bean. Phytopath. **5**: 303-311, figs. 1-4, 1915.

[8] Burkholder, Walter H. The production of an anthracnose-resistant White Marrow bean. Phytopath. **8**: 353-359, 1918.

[9] Reddick, Donald, and Stewart, Vern B. Varieties of beans susceptible to mosaic. Phytopath. **8**: 530-534, 1918.

* Indicates that slight or no infection was secured with one or two inoculations mostly in the field, but not with enough of them to permit classification with another group.

were different from strains α and β in their parasitic relationship by using each in inoculating certain criterion varieties that have shown a uniform response to inoculations and that represent the following four groups:—aB, Ab, ab, and AB.

The results of these inoculations show as far as these varieties will indicate that cultures G, Q, and S are identical with strain α and that cultures K and R may be referred to strain β. It is interesting to note that all cultures made from pea beans, regardless of the source, invariably fall under strain α, and that culture R secured from an affected White Kidney bean falls, as one might suppose, under strain β. There is not complete uniformity in the response of many of the varieties to inoculations with these various cultures. These differences may be due to a slight variation within the strain itself. But special consideration must be given culture K, which has shown from later inoculations on certain California and Asiatic varieties a decided variation from what was expected. From table 3 one would conclude that culture K, with possibly two exceptions, is closely related to strain β, but in these latter varieties, as shown in table 4, it appears, except for three varieties, to be related to strain α. It will be noted that the exceptions in both these cases occur in connection with inoculations made on the Ab group of varieties.

All varieties listed in tables 3 and 4 were planted in each of three separate plats in the greenhouse at different times. One plat was inoculated with culture K at one time, the second with culture R two months later, and the third with culture S at still another time. This unexpected variation, therefore, cannot be due to mislabeling either the cultures or the beans. After all, nature is not so poor in her ability to create that only two biologic strains of an organism can be produced. It is well known that several strains or types of certain other pathogenic organisms exist. Very likely several other strains of this organism could be found if an extensive search were made for them. One can readily conceive how by long association with its particular host there may be as many strains of the parasite as there are well-defined varieties of beans, the difference between the strains not being of such a character as to inhibit in every instance an infection of varieties other than the one with which it is associated. This idea has been expressed earlier and while experiments recorded have given rather conflicting results, they have not furnished sufficient evidence either to prove or disprove the theory.

Early in this investigation preliminary attempts to break down the resistance of certain varieties to a given strain by means of heavy fertilization with nitrate of soda, by heavy continued watering, by shading, by stunting the plant through withholding water, and by injuring the plant mechanically in scraping the epidermis and in girdling just before inocu-

TABLE 3

Data from inoculation of criterion varieties with cultures secured from various sources Figures included with symbols refer to number of seedlings

GROUP	VARIETY NUMBER	CULTURES				
		G	K	Q	R	S
aB	76	E	N-S	E	N	E
	83	E	N-S	E	S	E
	98	E	N	E	N	E
	125	E	N-S	E		E
	140	E	N-S	E	N-S	E
Ab	9		G-E	N	E	
	88	N-S	E	16N 1F 2E	E	vS-S
	106	N	4N 10F 6E	N	E	10S 1F 2G 2E
	110	N	G-E	9N 1E	E	N-vS
	213	N	2N 1S	N	E	N
aB	13	E	G	E	E	E
	31	E	G	E	E	E
	34	E	G	E	E	E
	57	G-E	F-G	G-E	G-E	G-E
	121	G-E	E	E	E	E
AB	88a	N	3N 8S 5F1 E	N	S	
	101	S	N–S	N–S	N–S	vS–S

TABLE 4

Results of inoculations of certain California and Asiatic varieties of Phaseolus vulgaris with cultures R, K and S

VARIETY NUMBER	G	K	Q	R	S
222	E	E	E	27N 8S 1F 3E	E
223	E	E	E	13N 26S	E
224	E	E	E	12N 4S 16F 2G 7E	E
225	19N 1E	16N 3E	16N 3E	14S 2F 2G 3E	18vS 1E
226	G-E	E	E	3N 17E	E
227	E	E	E	G	E
400		N-S	N-S	E	N-S
401		N-S	N-S	E	N-S
402		9N 11E	9N 11E	11S 4F 3E	E
403		E	E	N-S	E
404		F	F	N-S	E
405		E	E	F	E
406		E	E	4N 10S 4F	E
407		12G 4F	N-S	G-E	4N 12S 3F
408		E	E	N-S	E

lations were made, resulted in every case in failure to secure any greater degree of infection from inoculations made than that secured in plants not so treated.

It has been previously reported[10] that Wells' Red Kidney has shown a remarkable resistance to anthracnose, whereas the ordinary Red Kidney is very susceptible to strain F (β), although resistant to strain α. Subsequent trials of this anthracnose-resistant bean have confirmed the earlier observations. It has proved to be resistant at every locality in which it has been tried as far as reported, and in all attempts to inoculate it in the greenhouse under conditions that permit excellent infection of susceptible varieties. It cannot be said to be immune, because often, when seedlings are inoculated with strain β, numerous lesions appear on the epicotyl, so that it looks badly affected. But it seems to outgrow this without difficulty and subsequent infections are light and apparently do little or no injury. In greenhouse inoculations of a number of seedlings of this strain of Red Kidney one can usually find individuals showing no lesions whatever except very fine specks often quite numerous along the stem, petioles, and leaf veins. These have also been observed on several other varieties when inoculated with the strain of *C. lindemuthianum* to which they are resistant.

Wells' Red Kidney should serve as foundation stock by means of which this desirable character of anthracnose-resistance may be introduced by hybridization into other commercial varieties. Already Burkholder[11] has been able to obtain by this means a White Marrow and other types of beans resistant to anthracnose, and further work of this kind is being carried on by others.

A variety known in western New York as White Imperial has been found also to possess anthracnose-resisting properties. Several years ago a large field of these beans was observed to be free from this disease when most beans in the neighborhood were affected. Samples of this variety were secured from several sections of the State, and from time to time seedling plants have been included with other varieties in inoculations made with various cultures. Of 195 White Imperial seedlings inoculated in this way only two gave good infections, 127 slight or very slight, and 66 none. If this variety remains as resistant to anthracnose as these experiments seem to indicate, it will be a valuable one for future work. The plant forms a large bush like White Kidney and is a rather late grower. The seed is medium in size, plump, oblong, and veiny-white. It is not grown extensively, probably because of its lateness and because it is not

[10] Barrus, 1915, loc. cit.

[11] Loc. cit.

quite as marketable as the Navy Pea and White Marrow, but it may be found in a few localities of western New York. Strain β is the only one that is able to produce any lesions upon either of these resistant varieties. Strain α gives no evidence whatever of infection.

As can be seen from table 4, the variety No. 225, Western Red Kidney, shows high resistance from all inoculations in case of most individuals. There were in every case a few plants that were very susceptible.

This difference in strains of the pathogene in its ability to infect varieties of beans may account for the difference sometimes observed in a variety in its susceptibility in different localities. Yellow Eye seems to be resistant to anthracnose at Grand Isle, Vermont, while Navy Pea there is susceptible; but the Yellow Eye was this year badly affected with anthracnose in some parts of Maine. This seems to indicate that only strain α occurs at Grand Isle, while strain β, at least, occurs in those parts of Maine. However, bean seed of many varieties has been so widely disseminated throughout the country, it is improbable that any bean growing locality should not have had the two strains introduced at some time. In some localities a single variety largely predominates and should this belong to the Ab or aB group, as most field beans do, one would naturally find the strain affecting that variety to predominate there, as the other having few host plants could not spread far.

Inoculations have been made with either or both of strains α and β on cultivated varieties of other species of Phaseolus and of related genera. Summarized results of these are given in the index to the varieties. It can be seen there that several varieties of *Phaseolus lunatus* L. have shown fair and in some cases good infection (plate VA). Most varieties gave slight or no infection. There is some indication that the same variation exists in susceptibility to different strains of the pathogene as with varieties of *P. vulgaris*, but as no variety of the species is nearly as susceptible, this difference in response to strains is scarcely measurable.

Some plants of a few varieties of *P. multiflorus* Willd., *P. aconitifolius* Jacq., and *P. aureas* Roxb. gave slight infection (plate Vb) and a greenish-white seeded variety of tepary bean, *P. acutifolius* var. *latifolius* G. F. Freeman gave good to excellent infection. Good infection was also secured with both strains on a few plants of one variety of the black-eye bean, *Vigna sinensis* (L) Endl. Very slight infection occurred on a few plants of the varieties Yard Long and Cuban Asparagus of *Dolichos sesquipedalis* L. and on *Dolichos biflorus*, L., also on a few plants of the Guar bean, *Cyamopsis tetragonolobus* Taub., and small lesions were observed on one cotyledon of two plants of the Jack bean, *Canavali ensiformis* (L) D. C. Peas, cucumbers, young mandrake plants, and sweet

peas have been inoculated with *C. lindemuthianum* but no infection occurred in any case.

These trials indicate that there are several species of Phaseolus and also species of other genera that may become affected with anthracnose to some extent, but they are not favorable host plants for the parasite. There are probably several other wild and cultivated plants related to *Phaseolus vulgaris* that would show restricted susceptibility. It is interesting to note the rather marked susceptibility of seedlings of black-eye bean or cowpea to anthracnose. This variety was obtained from California, where it is extensively grown. Possibly other varieties of cowpea would not be as susceptible, for the disease has hardly ever been reported as occurring on the plant. Chester,[12] however, records an instance where the disease had damaged seedlings of the Couch variety to a considerable extent and an examination of the seed with which they were planted revealed many spotted ones.

The question naturally arises whether the resistance of certain varieties of *Phaseolus vulgaris* to a strain of the pathogene is due to the same factors as those which are responsible for the resistance of other species of Phaseolus. If it be so, one might conclude a priori that the resistance of other plants more or less distantly or not at all related to Phaseolus is due to these same factors. However, the fact that these varieties of *Phaseolus vulgaris* are susceptible to another strain of the same pathogene, while the more distantly related plants are resistant leads one to conclude that the combination of factors must be somewhat different in the two cases. There may be many combinations of these factors and the pathogene respond differently in each case, the response manifesting itself in a variation in the resistance of the host plant.

The data presented here are sufficient to arouse interest and speculation concerning causes of resistance but much additional information must be obtained before we can form sound conclusions. The bean plant is well adapted to studies of this kind because of its size, its ease of culture, its comparatively short period of growth, its habit of self-fertilization, its large number of well-marked varieties, and its varietal variation in susceptibility to certain diseases. *Colletotrichum lindemuthianum* is a very satisfactory pathogene to use because of the ease with which it can be cultured, the great abundance of an inoculating medium produced, and the existence of more than one strain of the organism. The resistance of varieties of beans to several other diseases can also be readily studied from artificial inoculations. It is hoped that those persons adequately

[12] Chester, F. C. Diseased Cowpea Seed. Del. Agr. Exp. Sta. Rpt., **1893**: 110–111. 1894.

trained and having a leaning for this kind of work may utilize the bean plant to the fullest extent in this most interesting and important study of causes of resistance to disease.

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INDEX TO BEAN VARIETIES AND SPECIES INOCULATED AND A SUMMARIZED STATEMENT REGARDING THEIR SUSCEPTIBILITY TO STRAINS A AND B OF COLLETOTRICHUM LINDEMUTHIANUM (SACC. & MAGN.) B & C.

PHASEOLUS VULGARIS L.

WAX-PODDED BUSH BEANS

1. Bismark.—Apparently susceptible to α.
3. Burpee Kidney.—Very susceptible to both strains.
4. Burpee White Wax.—Very susceptible to both strains.
5. Challenge Black Wax.—Very susceptible to both strains.
6. Crystal Wax.—Very susceptible to α; apparently resistant to β although several field inoculations gave fair to excellent infection.
7. Currie.—Somewhat susceptible to α; very susceptible to β.
8. Davis.—Very susceptible to both strains.
9. Detroit.—Very resistant to α; susceptible to β.
10. Double Barrel.—Susceptible to both strains.
11. Dwarf Butter.—Susceptible to both strains.
12. Flageolet Wax.—Susceptible to both strains although three of the field inoculations gave fair to no infection.
197. Fuller's White Wax.—Very resistant to α; was not inoculated with β.
13. German Black Wax.—Very susceptible to both strains.
15. Golden Crown.—Very susceptible to most inoculations with both strains.
16. Golden Eyed Wax.—Susceptible to both strains, but certain field inoculations gave only fair to no infection.
17. Golden Wax.—Susceptible to both strains, but most field inoculations gave only fair to no infection.
200. Hardy Wax.—Very susceptible to both strains.
18. Hodson Wax.—Susceptible to both strains although field inoculations gave only fair to no infection.
19. Horticultural Wax.—Very susceptible to both strains.
20. Imperial.—Very resistant to α; very susceptible to β.
21. Improved Golden Wax.—Very resistant to α; very susceptible to β.
22. Jones Stringless.—Very susceptible to both strains except with two inoculations.
23. Keeney Rustless.—Susceptible to both strains from greenhouse inoculations on seedlings, but only fair to no infection from field inoculations.
24. Leopard.—Very susceptible to both strains.
25. Lima Wax.—Very susceptible to α; very resistant to β.
26. Market Wax.—Very susceptible to both strains.
212. Michigan White Wax.—Susceptible to both strains.

28. Monarch.—Susceptible to both strains.
29. Pencil Pod Black Wax.—Very susceptible to both strains.
30. Perfection.—Very susceptible to both strains.
31. Prolific Black Wax.—Very susceptible to both strains.
33. Refugee Wax.—Very susceptible to α; not quite as susceptible to β.
34. Round Pod Kidney.—Very susceptible to both strains.
35. Scarlet Flageolet.—Susceptible to both strains, although a few inoculations with A gave fair to no infections, others giving excellent.
36. Speckled Wax.—Susceptible to both strains, very much so to β. In two inoculations out of five with α only fair to no infection was secured, the others being excellent.
37. Stringless Refugee Wax.—Susceptible to both strains, but fair to no infection was obtained from a few inoculations with both strains.
38. Valentine Wax.—Very susceptible to both strains.
39. Wardwell.—Very susceptible to both strains.
207. Webber Wax.—Very susceptible to both strains.
40. Wingold.—Very susceptible to both strains.
41. Yosemite.—Very susceptible to both strains.

GREEN-PODDED BUSH BEANS

43. Best of All.—Susceptible to both strains, but only fair to slight infection was secured from a few of the inoculations with both.
44. Black Prince.—Susceptible to both strains.
45. Black Valentine.—Susceptible to both strains.
46. Blue Pod Butter.—Very resistant to α; susceptible to β.
214. Blue Pod Medium.—Very susceptible to α; very resistant to β.
47. Boston Favorite.—Susceptible to both strains.
48. Bountiful.—Susceptible to both strains. Certain inoculations gave slight to no infection.
49. Burlingame.—Very susceptible to α; resistant to β.
50. Burpee Stringless.—Very susceptible to both strains.
51. Byer.—Very susceptible to both strains.
52. Canadian Wonder.—Susceptible to both strains but gave slight to no infection from a majority of inoculations with α and from a few of those with β.
53. China Red Dye.—Resistant to α; susceptible to β.
54. Cream Valentine.—Susceptible to both strains.
55. Crimson Beauty.—Susceptible to both strains.
56. Early Market.—Very susceptible to α; resistant to β.
57. Early Refugee.—Susceptible to both strains.
59. Emperor William.—Susceptible to α; resistant to β.
60. Eureka.—Susceptible to both strains.
61. Everbearing.—Showed considerable resistance in most inoculations with both strains but some inoculations with α gave good to excellent infection and from one with β two plants showed good infection.
62. French Cholet.—Susceptible to both strains, although two field inoculations with β gave no infection.
63. French Kidney.—Susceptible to both strains.
64. French Mohawk.—Susceptible to both strains.
65. Full Measure.—Susceptible to both strains.

66. Galega.—Susceptible to both strains although two field inoculations gave slight to no infection.
67. Garden Pride.—Very susceptible to both strains.
202. Giant Forcer.—Susceptible to both strains in later inoculations. Earlier inoculations indicated resistance.
68. Giant Stringless.—Susceptible to both strains.
69. Golden Refugee.—Susceptible to α; resistant to β with most inoculations.
70. Green Flageolet.—Susceptible to α; somewhat resistant to β although good to excellent infection was secured on a few plants in four greenhouse and field inoculations.
71. Grenell Stringless.—Somewhat susceptible to α; very much so to β.
72. Hodson Green Pod.—Somewhat susceptible to α; very much so to β.
74. Improved Goddard.—Somewhat resistant to α; although the first inoculations showed susceptibility; susceptible to β.
204. Keeneys' Stringless Green Refugee.—Susceptible to both strains.
75. Knickerbocker.—Somewhat susceptible to α; very susceptible to β.
76. Lady Washington.—Very susceptible to α; resistant to β.
78. Longfellow.—Susceptible to α; very much so to β.
79. Low Champion.—Very resistant to α; susceptible to β.
80. Marblehead Horticultural.—Susceptible to both strains.
81. Mexican Pinto.—Very susceptible to both strains.
82. Mohawk.—Somewhat susceptible to α; very susceptible to β.
83. Navy Pea.—Very susceptible to α; resistant to β.
84. Ne Plus Ultra.—Susceptible to both strains.
206. Osborns Forcing.—Somewhat susceptible to α, except from five inoculations when slight to no infection was obtained; very susceptible to β.
85. Old Fashioned Yellow Eye.—Earlier inoculation with α, gave good infection but the variety has been very resistant to later ones; susceptible to β.
86. Prolific Market.—To two inoculations with α and one with β the variety has been very susceptible.
88. Red Kidney.—Very resistant to α; very susceptible to β.
88a. Red Kidney, Wells.—Resistant to both strains.
213. Red Marrow.—Resistant to α; very susceptible to β.
89. Red Valentine.—Susceptible to both strains, but with four inoculations no infection was obtained.
90. Refugee.—Susceptible to both strains.
91. Reliance.—Three inoculations with α gave good to excellent infection.
92. Round Six Weeks.—Susceptible to both strains.
93. Ruby Horticultural.—Susceptible to both strains.
199. Rust Proof Intermediate Horticultural.—Susceptible to both strains.
94. Pheasant Eye.—Susceptible to both strains.
95. Snow Flake.—Very susceptible to α; resistant to β, except with three inoculations when good to excellent infection was obtained.
203. Stringless Green Pod.—Very susceptible to both strains.
96. Swedish.—Susceptible to both strains.
97. Taylor Green Pod.—Very susceptible to both strains.
98. Tennessee Green Pod.—Susceptible to α; very resistant to β.
99. Tom Thumb.—Susceptible to α in the four inoculations made.
100. Triumph.—Susceptible to α; apparently resistant to β, except in one field inoculation when good infection was obtained.

101. Turtle Soup.—Although earlier inoculations gave some excellent infections with α and in one case with β, most of the inoculations with both strains have given only fair to no infection.
102. Veitch Forcing.—Susceptible to both strains, except in one field inoculation with β which gave no infection.
103. Veitch Wonder.—Susceptible to both strains.
104. Vienna.—Susceptible in case of one inoculation with unrecorded strain.
105. Vineless Marrow.—Somewhat resistant to α, except with one field inoculation when good infection was obtained; very susceptible to β.
106. Warren.—Very resistant to α; very susceptible to β.
107. Warwick.—Susceptible to both strains.
216. White Imperial.—Resistant to both strains.
109. White Kidney.—Very resistant to α; very susceptible to β.
110. White Marrow.—Very resistant to α; very susceptible to β.
114. Wonder of France.—Susceptible to both strains.
115. Yankee Winter.—Two inoculations with α, outside gave slight infection; no inoculations were made with β.
116. Yellow Cranberry.—Somewhat resistant to α, except with earlier inoculations when good infection was obtained; very susceptible to β.
117. Yellow Eye.—Very resistant to α; very susceptible to β.
118. Yellow Six Weeks.—Susceptible to α; very much so to β.

WAX-PODDED POLE BEANS

119. Andalusia.—Susceptible in two inoculations made with α; was not inoculated with β.
120. Black German Pole.—Resistant to α; very susceptible to β.
121. Golden Carmine.—Very susceptible to both strains.
122. Golden Champion.—Susceptible to both strains.
123. Golden Cluster.—Susceptible to α; somewhat resistant to β, except with three inoculations when good to excellent infection was obtained.
124. Indian Chief.—Resistant to α; susceptible to β.
125. Kentucky Wonder Wax.—Very susceptible to α, except with one field inoculation when no infection was obtained; resistant to β.
126. Landreth.—Susceptible to both strains.
127. Mont d'Or.—Resistant to α; very susceptible to β.
128. Sunshine.—Very susceptible to both strains.

GREEN-PODDED POLE BEANS

129. Arlington Red Cranberry.—Somewhat susceptible to both strains although no infection was obtained with six inoculations and some plants showed resistance in all except five inoculations out of twenty-one.
130. Black Kentucky Wonder.—Very susceptible to α; resistant to β.
132. Brockton.—Resistant to α; very susceptible to β.
133. Burger Stringless.—Susceptible to α, except in one field inoculation when no infection was obtained; resistant to β, except in one field inoculation which gave good infection.
134. Case Knife.—Very susceptible to α; resistant to β.

135. Childs Horticultural.—Very resistant to α; susceptible to β, except with three field inoculations when no infection was obtained.
137. Creaseback.—Susceptible to α, except in one field inoculation when no infection was obtained; resistant to β.
138. Cut Short.—Susceptible to α; resistant to β, except in one field inoculation and with six plants out of eighteen inoculated in greenhouse when good to excellent infection occurred.
139. Early Horticultural.—Somewhat susceptible to both strains although showing resistance to each in a few inoculations and having some plants resistant with others susceptible in other inoculations.
140. Kentucky Wonder.—Very susceptible to α, resistant to β, except in one field inoculation which gave good infection.
141. Lazy Wife.—Susceptible to both strains.
142. London Horticultural.—Susceptible to both strains although some individuals in each of three inoculations showed no infection.
143. Missouri Wonder.—Susceptible to both strains.
144. Powells Prolific.—Very susceptible to α; resistant to β.
145. Red Cranberry.—Susceptible to both strains although slight or no infection was obtained with a few inoculations.
146. Royal Corn.—Very susceptible to α; resistant to β, except with one field inoculation which gave good infection.
147. Scotia.—Susceptible to α, except in one inoculation when fair to no infection was obtained; resistant to β.
148. Southern Prolific.—Susceptible to α; resistant to β, except in one field inoculation which gave fair to good infection.
149. Tennessee Wonder.—Susceptible to α; somewhat susceptible to β although fair to good infection was obtained from some inoculations.
150. White Prolific.—Susceptible to both strains.
151. White Seeded Butter.—Slight to fair infection obtained with one inoculation with β; was not inoculated with α.
152. White Sickle.—Susceptible to both strains with the five inoculations made.
153. Worcester Mammoth.—Resistant to α, except for one greenhouse inoculation when a few plants showed good infection and others none; susceptible to β.
199. Rust Proof Intermediate Horticultural.—(See green-podded bush.)
200. Hardy Wax.—(See wax-podded bush.)
202. Giant Forcer.—(See green-podded bush.)
203. Stringless Green Pod.—(See green-podded bush.)
204. Keeney's Stringless Green Refugee.—(See green-podded bush.)
206. Osborn's Forcing (See green-podded bush.)
207. Webber Wax.—(See wax-podded bush.)
212. Michigan White Wax.—(See wax-podded bush.)
213. Red Marrow.—(See green-podded bush.)
214. Blue Pod Medium.—(See green-podded bush.)

CALIFORNIA VARIETIES

219. Mexican Red.—Apparently resistant to α; very susceptible to β.
220. Tepary.—(See *Phaseolus acutifolius*.)
222. Small White or Navy.—Very susceptible to α; somewhat resistant to β.
223. Blue Pod Navy.—Very susceptible to α; resistant to β.

224. California Pink.—Very susceptible to α; somewhat resistant to β.
225. Western Red Kidney.—Somewhat resistant to both. Most plants with each inoculation were very resistant; a few were quite susceptible. This variety obtained from Barnard and Bunker, San Francisco, California, has dark crimson seed and a different type of vine than ordinary Red Kidney.
226. Bayo.—Very susceptible to both strains.

ASIATIC VARIETIES

400. Chunaga uzura, mottled medium.—Resistant to α; very susceptible to β.
401. Nagauzura, mottled kidney.—Resistant to α; very susceptible to β.
402. Kotenashi, small white pea.—Susceptible to α; somewhat resistant to β, a few individuals being susceptible.
403. Chutenashi, white medium.—Very susceptible to α; resistant to β.
404. Chufuku, small white butter.—Very susceptible to α; resistant to β.
405. Muroingen, medium white butter.—Very susceptible to α; somewhat resistant to β.
406. Diafuku, large white butter.—Very susceptible to α; resistant to β.
407. Kintoki, dark red marrow.—Very resistant to α; susceptible to β.
408. Kumamoto ingen, slender white kidney.—Very susceptible to α, resistant to β.

PHASEOLUS LUNATUS L.

SMALL OR SIEVA LIMA

Bush varieties

155. Henderson.—Slight to fair infection, from nine out of fourteen inoculations, no infection obtained from others.
157. Willow Leaf Bush.—Slight infection from one inoculation out of two.
158. Wood Prolific.—Slight infection from five inoculations out of nine.

Pole varieties

160. Carolina.—Slight to fair infection from seven out of ten inoculations.
162. Wood Improved.—Slight to fair infection from six out of ten inoculations.

LARGE LIMA

Bush varieties

163. Burpee.—Slight to fair infection from six out of eight inoculations.
164. Burpee Improved.—Fair to good infection obtained from six out of eight inoculations. Strain α produced somewhat greater infection than β.
166. Fordhook.—Fair to good infection from nearly all inoculations.
167. Wonder.—Slight to good infection from all inoculations.

Pole varieties

168. Challenge.—Slight to good infection from nearly all inoculations.
169. Dreer Pole.—Slight to fair infection from the four inoculations made.
170. Ford Mammoth.—Slight to good infection from seven out of eleven inoculations.
171. Garden King.—Slight to fair infection from the four inoculations made.

173. Golden Lima.—Slight infection from the one inoculation made with β in field plat.
174. Ideal.—Slight to fair infection from the four inoculations made with β.
175. Jersey.—Slight to fair infection from eight inoculations.
176. Large White.—Slight to no infection from the three inoculations made with strain β.
177. Leviathan.—Slight to good infection from eleven out of twelve inoculations.
178. Long Pod.—Fair infection from most inoculations; good with one.
181. Panmure.—No infection from the one inoculation which was made with strain β in field plat.
182. Salem.—Fair to good infection from five out of nine inoculations.
183. Siebert.—Fair to good infection from thirteen out of fourteen inoculations.

PHASEOLUS MULTIFLORUS WILLD.

MULTIFLORA BEANS

Pole varieties

187. Scarlet Runner.—Slight infection from three and fair from one out of fifteen inoculations.
188. White (Dutch) Runner.—Slight infection from three and fair from one out of seventeen inoculations.
211. Arabian Runner.—Slight infection from three and fair from two out of fourteen inoculations.

PHASEOLUS ACUTIFOLIUS GRAY VAR. LATIFOLIUS G. F. FREEMAN

TEPARY BEAN

220. White Tepary.—Very susceptible to both strains.

PHASEOLUS ACONITIFOLIUS JACQ.

MOTH BEAN

276. S. P. I.[13] No. 22761.—No infection with strain α; very slight indication of infection on petioles and midrib with strain β.

PHASEOLUS ANGULARIS (WILLD.) W. F. WIGHT

ADZUKI BEAN

278. S. P. I. No. 17851.—No infection obtained with either strain.
279. S. P. I. No. 17847.—No infection obtained with either strain.
285. Selection obtained from Dr. A. F. Blakeslee, Cold Spring Harbor, N. Y.—No infection with either strain.
301. S. P. I. No. 20010.—No infection obtained with a mixed culture of both strains.
302. S. P. I. No. 20010a (selection from No. 20010).—No infection obtained with a mixed culture of both strains.

[13] S. P. I. numbers given in index refer to numbers given by the United States Department of Agriculture to Foreign Seed and Plant Introductions.

303. S. P. I. No. 25916.—No infection from an inoculation with a mixture of both strains.
306. S. P. I. No. 34959.—No infection from an inoculation with a mixture of both strains.
307. S. P. I. No. 34961.—No infection from an inoculation with a mixture of both strains.
308. S. P. I. No. 34963.—No infection from an inoculation with a mixture of both strains.
310. S. P. I. No. 36085.—No infection from an inoculation with a mixture of both strains.

PHASEOLUS AUREUS ROXB.

MUNG BEAN

210. Chinese Sago, from Aggeler and Musser Seed Co., Los Angeles, Cal.—Slight infection secured on leaf-veins and pods from eleven out of twenty inoculations with both strains.
280. S. P. I. No. 35629.—Slight or very slight infection on epicotyl and leaf vines from inoculations with both strains.
311. S. P. I. No. 17303.—Fair infection from an inoculation with a mixture of both strains.
312. S. P. I. No. 21788.—No infection from an inoculation with a mixture of both strains.
313. S. P. I. No. 34776.—Very slight infection on veins from an inoculation with a mixture of both strains.

PHASEOLUS CALCARATUS ROXB.

RICE BEAN

315. S. P. I. No. 01978.—No infection from an inoculation with a mixture of both strains.
316. S. P. I. No. 17850.—No infection from an inoculation with a mixture of both strains.
317. S. P. I. No. 30730.—No infection from an inoculation with a mixture of both strains.
319. S. P. I. No. 33098.—No infection from two inoculations with a mixture of both strains.

PHASEOLUS MUNGO L.

URD BEAN

321. S. P. I. No. 17306.—No infection from an inoculation with a mixture of both strains
322. S. P. I. No. 21789.—No infection from an inoculation with a mixture of both strains.

PHASEOLUS SEMIERECTUS L.

323. S. P. I. No. 24639.—No infection from an inoculation with a mixture of both strains.

VIGNA SINENSIS (L) ENDL.

COWPEA

287. California Blackeye.—Somewhat susceptible to both strains. Part of the plants inoculated showed fair to excellent infection and the others slight to no infection.

VIGNA SESQUIPEDALIS (L) W. F. WIGHT

ASPARAGUS BEAN

192. Yard Long.—Slight infection on pedicel and leaf-veins from seven out of nineteen inoculations.
198. Cuban Asparagus.—Slight infection in pedicel and leaf-veins from six out of sixteen inoculations.

DOLICHOS LABLAB L.

HYACINTH OR BONAVIST BEAN

275. S. P. I. No. 8686.—No infection obtained with either strain.

DOLICHOS BIFLORUS L.

KULTHI BEAN

277. S. P. I. No. 32612.—No infection obtained with either strain.

CANAVALI ENSIFORMIS (L) D. C.

JACK BEAN

284. S. P. I. No. 34991.—No infection obtained except for a small lesion that appeared on a cotyledon of two plants from an inoculation with strain **α**.

VICI FABA L.

ENGLISH BROAD BEAN

190. Bacon.—No infection with either strain from nine inoculations.
191. Prolific Broad Bean.—No infection with either strain from sixteen inoculations.
282. Horse Bean, S. P. I. No. 15429.—No infection with either strain from three inoculations.
283. Winter Horse Bean, Congressional No. 1570.—No infection with either str in from three inoculations.

CYAMOPSIS TETRAGONOLABOUS TAUB.

GUARANA

281. Congressional No. 1483.—A slight infection obtained on a cotyledon of one plant the others showing nothing from one inoculation with strain **α**; no infection from one inoculation with strain **β**; very slight infection on one plant and specks on several from one inoculation with a mixed culture of **α** and **β**.

CICER ARIETINUM L.

GARBANZO BEAN OR CHICK PEA

286. Variety unrecorded.—No infection obtained with either strain from two inoculations.

PISUM SATIVUM L.

GARDEN PEA

288. Variety unrecorded.—No infection obtained with either strain.

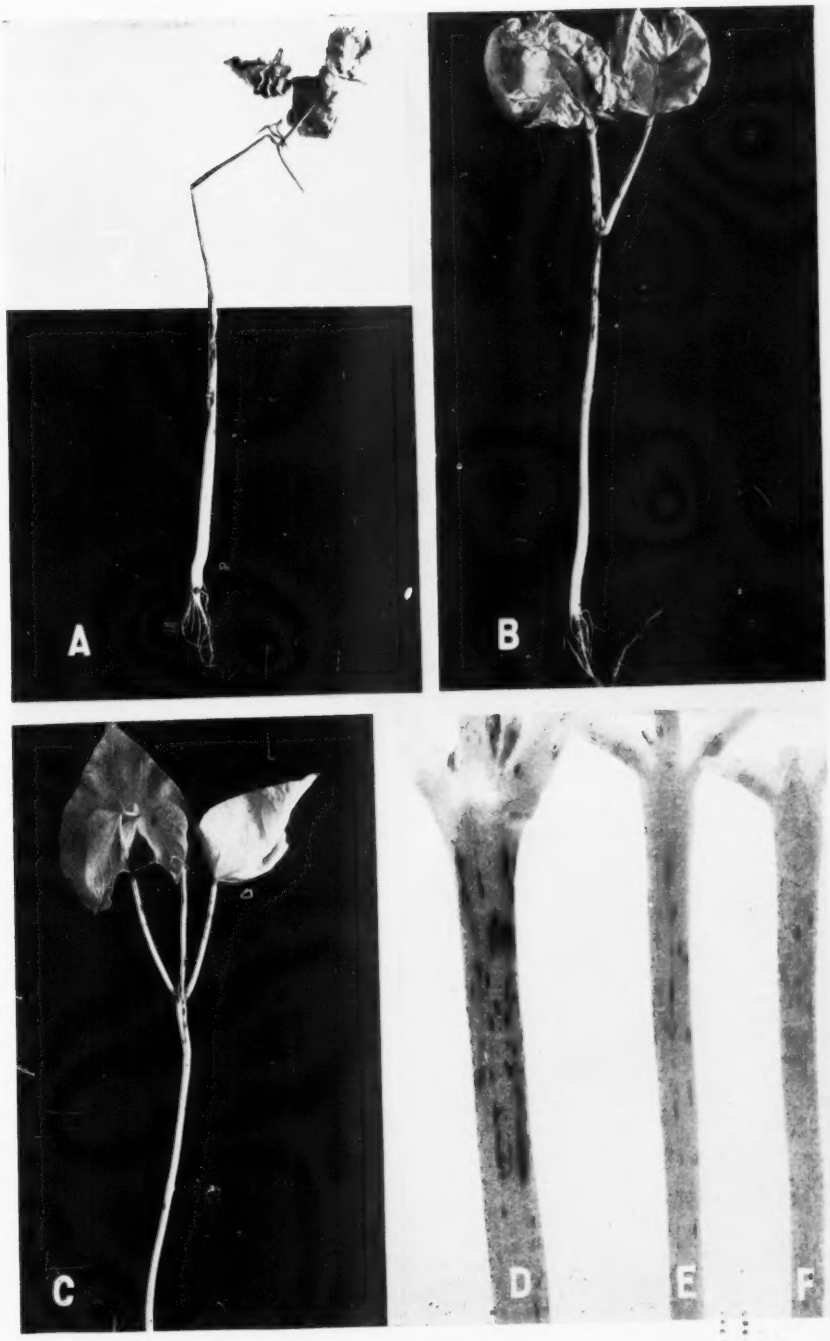
LATHYRUS ODORATUS L.

SWEET PEA.

345. Variety unrecorded.—No infection obtained with either strain.

PLATE I. DEGREES OF INFECTION ON BEAN SEEDLINGS

A, excellent; B, good; C, fair; D, slight; E, very slight, F, none.



BARRUS: SUSCEPTIBILITY OF BEANS TO ANTHRACNOSE

PLATE II. RESULTS OF INOCULATIONS OF VARIETIES OF BEANS WITH STRAIN A (CULTURE A) AND WITH STRAIN B (CULTURES F OR N)

The inoculation of the pots containing corresponding varieties was made at the same time and under the same conditions except for differences in the strain of the pathogene used.

A. Varieties 46 Blue Pod Butter (Ab) and 83 Navy Pea (aB) after inoculation with strain α.

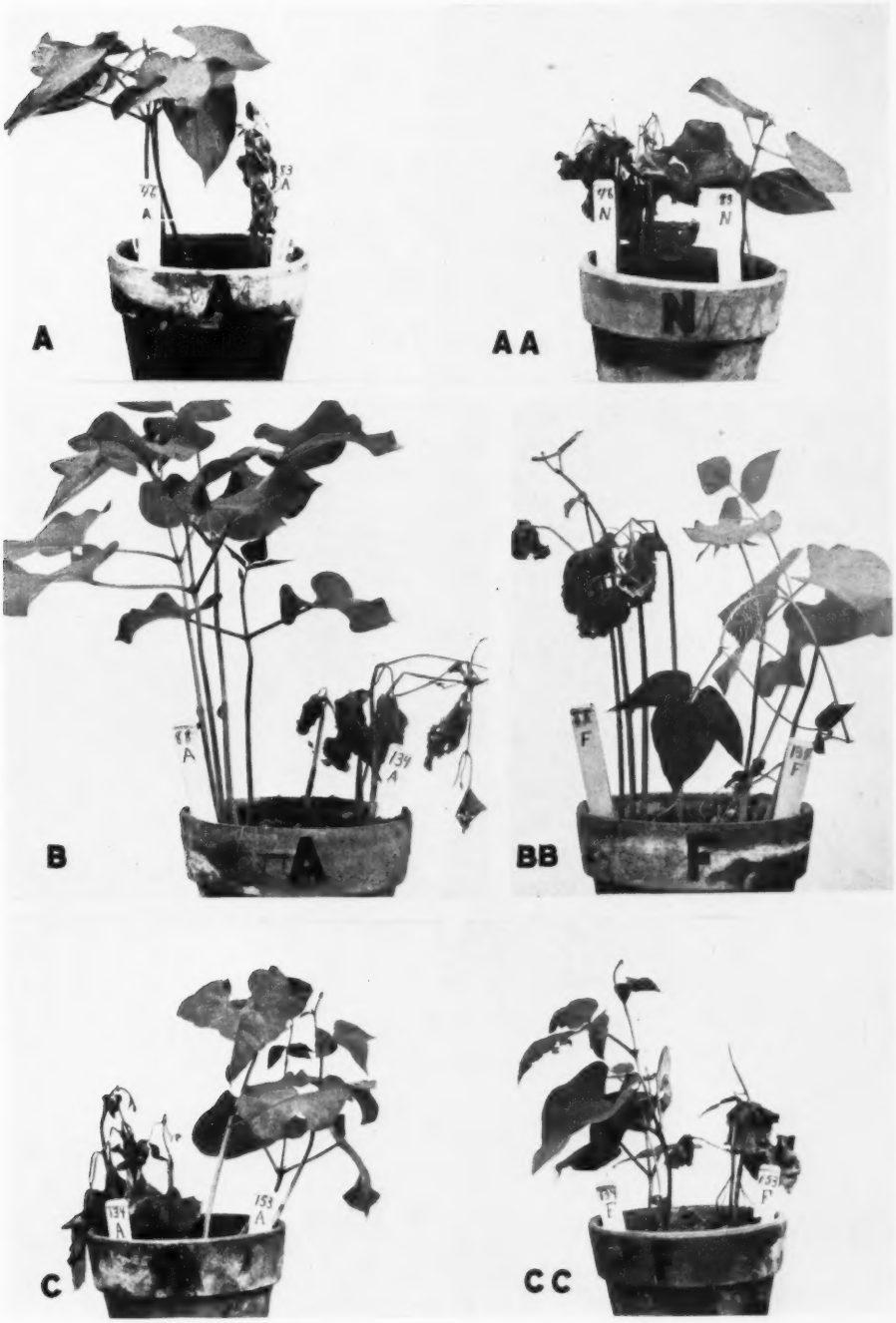
AA. Same varieties after inoculation with strain β.

B. Varieties 88 Red Kidney (Ab) and 134 Case Knife (aB) after inoculation with strain α.

BB. Same varieties after inoculation with strain β.

C. Varieties 134 Case Knife (aB) and 153 Worcester Mammoth (Ab) after inoculation with strain α.

CC. Same varieties after inoculation with strain β.



BARRUS: SUSCEPTIBILITY OF BEANS TO ANTHRACNOSE

PLATE III. CONTINUATION OF PLATE II

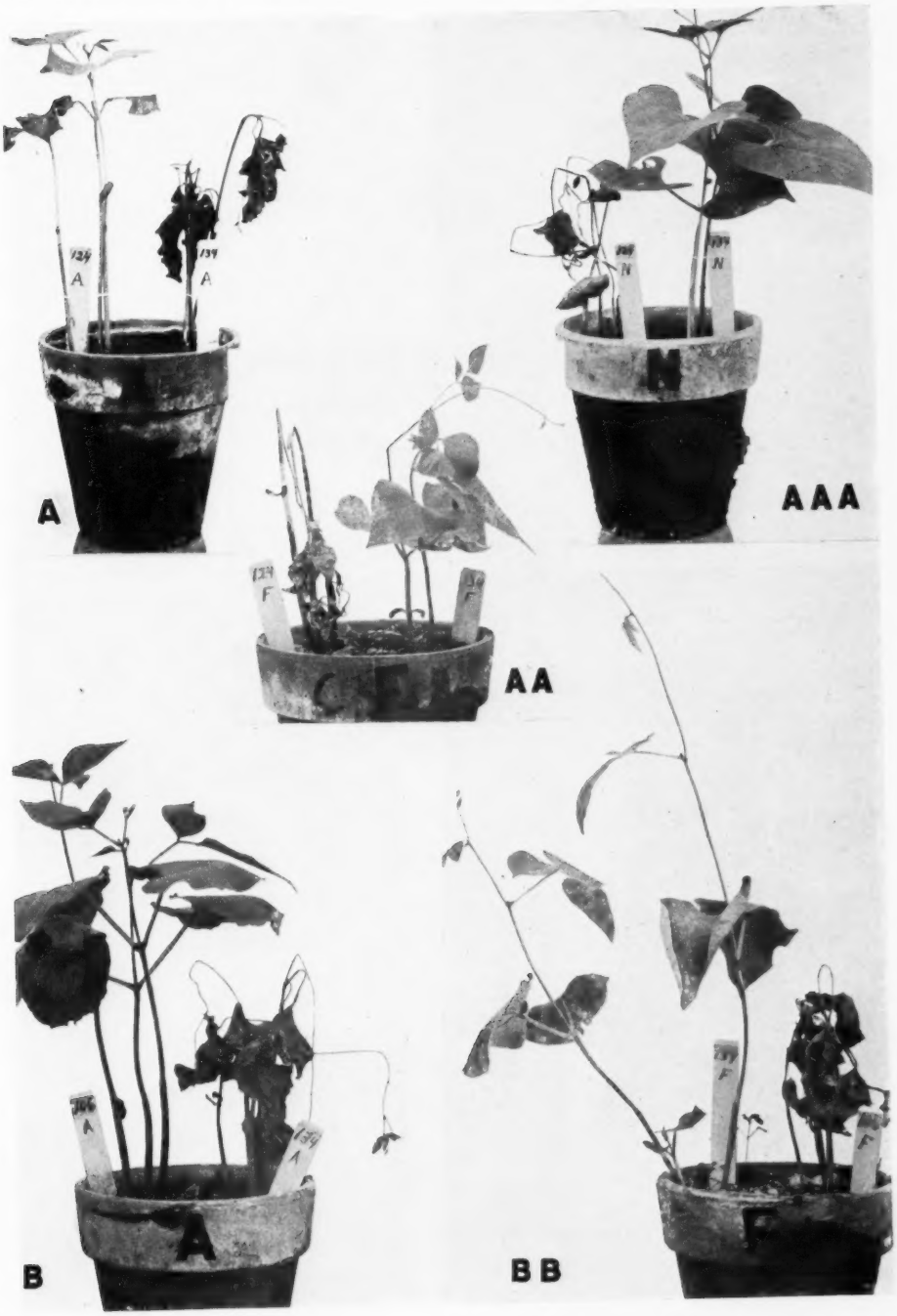
A. Varieties 124 Indian Chief (Ab) and 134 Case Knife (aB) after inoculation with strain α.

AA. Same varieties after inoculation with strain β (Culture F).

AAA. Same varieties after inoculation with strain β (Culture B).

B. Varieties 106 Warren (Ab) and 134 Case Knife (aB) after inoculation with strain α.

BB. Same varieties after inoculation with strain β.



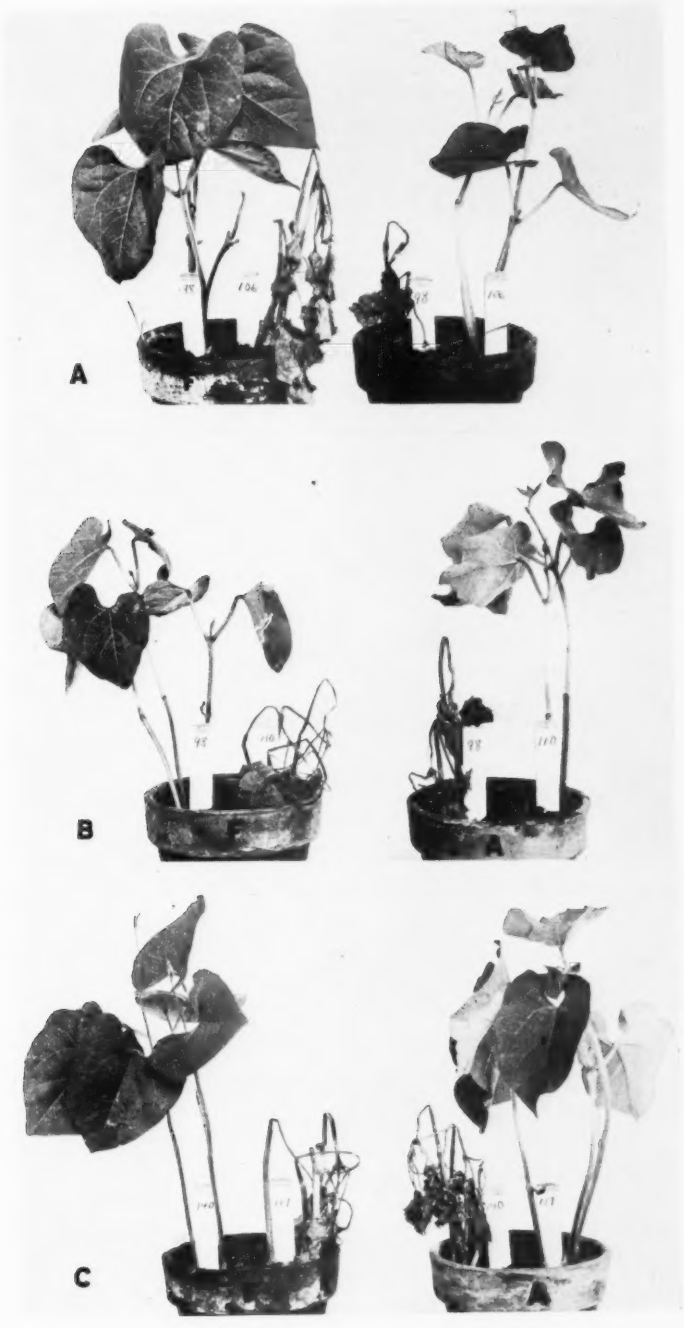
BARRUS: SUSCEPTIBILITY OF BEANS TO ANTHRACNOSE

PLATE IV. CONTINUATION OF PLATE III

A. Varieties 98 Tennessee Green Pod (aB) and 106 Warren (Ab) on the right inoculated with strain α, on the left with strain β.

B. Varieties 98 Tennessee Green Pod (aB) and 110 White Marrow (Ab) on the right inoculated with strain α, on the left with strain β.

C. Varieties 140 Kentucky Wonder (aB) and 117 Yellow Eye (Ab) on the right inoculated with strain α, on the left with strain β.



BARRUS: SUSCEPTIBILITY OF BEANS TO ANTHRACNOSE

PLATE V. RESULTS OF INOCULATION OF TWO OTHER SPECIES OF PHASEOLUS WITH COLLETOTRICHUM LINDEMUTHIANUM (SACC. & MAGN) B. & C.

A. Pods of *Phaseolus lunatus* L. var. Garden King lima showing good infection after an inoculation in the field with a mixed culture of strains α and β.

B. Pods of *Phaseolus multiflorus* Willd. var. White Dutch Runner after an inoculation in the field with a mixed culture of strains α and β.

BARRUS: SUSCEPTIBILITY OF BEANS TO ANTHRACNOSE

BRIEFER ARTICLES

WOOD-ROTS OF PEACH TREES CAUSED BY *CORIOLUS PROLIFICANS* AND *C. VERSICOLOR.*

JOHN A. ELLIOTT

Severe parasitic wood-rots of peach trees due to *Coriolus prolificans* (Fries) Murrill and *C. versicolor* (L.) Quel.[1] were observed by the writer as occurring near Lamar, Arkansas. Under usual conditions in Arkansas peach trees may be rather severely cut back without danger of rots attack-

FIG. 1. SEVERELY PRUNED PEACH TREE SHOWING NEW GROWTH, BUT THE OLDER WOOD ENTIRELY DESTROYED BY *Coriolus prolificans*

[1] The Fungi were identified by Dr. W. A. Murrill and by Miss Jean MacInnes, mycologist, University of Minnesota.

ing the exposed heart-wood to any great extent, but in this case almost every stub was the starting place of rots that ultimately destroyed the trees completely. Of the two fungi which appeared to be doing the most damage, *C. prolificans* was by far the more plentiful, some of the trees being almost entirely covered by its fruiting bodies. In other cases *C. versicolor* was equally destructive. *Picnoporus cinnabarinus* (Jacq.) Karst. and *Schizophylum commune* Fries were common on some of the decayed trees, but there was no evidence that they were the initial cause of the rots in any case.

FIG. 2. STUB OF A PEACH TREE SHOWING FRUITING BODIES OF *C. versicolor*, WHICH HAS ENTIRELY DESTROYED THE TREE

The parasitism of the fungi was evident from the fact that the trees had made a vigorous growth for one or two seasons following the cutting back, and had been checked by the destruction, not only of the heart-wood of the older parts of the trees, but of the sap-wood as well. Some of the trees had been broken to pieces by the failure of the old decayed trunk and limbs to support the weight of the new growth. None of the trees seemed to survive more than three seasons after being severely pruned.

Interesting features of the case were the evident vigorous parasitism or *C. prolificans* and *C. versicolor*, and also the fact that the destructiveness of the rots seemed to be limited to certain localities. The orchard in

question was on relatively low heavy soil. Other orchards in the vicinity, on higher ground and lighter soil, showed no signs of these rots, although some of the trees had been cut back with an ax or in some other crude fashion, leaving every opportunity of any kind of saprophytic or parasitic rot.

ARKANSAS EXPERIMENT STATION

THE OVERWINTERING OF *CRONARTIUM RIBICOLA* ON RIBES

H. H. YORK AND PERLEY SPAULDING

Experiment 1. On March 24, 1918, H. H. York and S. B. Detwiler collected at Beulah, Massachusetts, dead leaves of *Ribes vulgare* which were heavily infected the previous summer with *Cronartium ribicola* and which still remained on the bushes. The sporophores were blackened and apparently bore no viable spores. Uredospores were scraped off into a few drops of water and used by Spaulding to inoculate leaves of a healthy plant of *R. nigrum* in the experimental greenhouse at Washington, D. C., on April 1st. On April 16 a single uredinium was found on one of the inoculated leaves. No others developed. No uredinia developed upon the uninoculated leaves, nor on any of the adjacent uninoculated. plants. Van Tieghem cell tests of the spores gave no germination but it has since been learned that this is not the best method for germinating the spores of *Cronartium ribicola* so these tests were far from conclusive.

Experiment 2. A series of inoculations, with uredospores from leaves of Ribes which had remained out of doors since the season of 1917 on bushes of Ribes and on the ground beneath the same, were made by York on cuttings of *R. americanum* and *R. nigrum* in the greenhouse of the Department of Botany at Brown University, April 18, 1918. The material for these inoculations consisted in part of infected leaves of cultivated gooseberry at Swansea, Massachusetts, which had remained attached to the bushes all winter and which had opened late in the season of 1917. The other portion consisted of leaves of *R. nigrum* which were about one mile from the gooseberry bushes just mentioned. All of the leaves were collected on April 17, 1918. The cuttings of *R. americanum* used in these experiments were collected at Beulah, Massachusetts, March 24, 1918, when the buds were much swollen but not broken open; the others, of *R. nigrum*, were cut on April 17, 1918, from the bushes where the overwintered leaves were collected, and had their new leaves about one-third developed. They were all placed in flower pots containing sand and covered with bell jars. No fruiting material of any stage of *Cronartium ribicola* had been in the greenhouse prior to these inoculations. Aecia

shedding spores were noted by Barrus in eastern Massachusetts on April 15th. The nearest white pine was about 400 yards distant from the source of the over-wintered leaves, while the nearest diseased pine was two miles away. Before making the inoculations the old leaves were placed in moist chambers and set near a radiator in York's office for twenty-four hours. Five inoculations from the gooseberry leaves and fifteen from the currant leaves were made. The lower surface of the leaf to be inoculated was first thoroughly moistened with water. Then by means of a sharp scalpel the uredospores were scraped from the old leaves, under a binocular microscope, and smeared on the moistened leaf surface. From three to six smears were made on a single leaf. The upper surfaces of the leaves were sprayed daily with water. One uredo sorus on *R. nigrum* was first noticed on May 4, and on May 7 there were seven, all of which had broken open. The spores from which this infection resulted, came from a leaf of *R. nigrum* which had remained on the twig all winter.

Experiment 3. On April 17 another series of inoculation was made by York from herbarium material of *R. aureum* which had an abundance of uredo sori. This material was collected near North Conway, New Hampshire, August 17, 1917, and carefully dried between sheets of heavy glazed paper. On September 28, 1917, the paper with the specimens was placed in a locker in one of the botanical laboratories at Brown University where it remained until April 17, 1918, when a portion of the leaves was placed in moist chambers kept with those mentioned in experiment 2. Twelve inoculations from this material were made on *R. americanum* and *R. nigrum* as above described. Two uredo sori were visible on a single leaf of *R. americanum* on the morning of May 8. They were broken open on May 10, the period of development being nearly the same as with the material overwintered out of doors.

Experiment 4. On April 19, 1918, York removed several uredo pustules which had not broken open from the herbarium material of leaves of *R. aureum* which had been in the moist chamber forty-eight hours, crushed and examined them under the microscope. In the center of one of these masses of spores, one germinating uredospore was observed. The germ tube was at least 250 μ in length.

To summarize, we may state that Spaulding's positive results were secured from inoculations with uredospores which had overwintered naturally, with no possibility of contamination by newly formed aeciospores. The checks remained free from infection. York's experiments were successful but his material for inoculation was collected after aecia are known to have begun shedding spores in that general region. The absence of any pine for some distance makes contamination by aeciospores so early improbable. Moreover, test of the spores kept on dried leaves

over winter in the laboratory gave positive results, both in inoculations on Ribes and in situ. It seems then that *Cronartium ribicola* may occasionally overwinter on dead Ribes leaves, thus perpetuating the fungus in localities where pines are absent. This also emphasizes the danger of carrying the disease from infected to uninfected regions through the shipment of Ribes which have had the disease the previous season.

BUREAU OF PLANT INDUSTRY

OVERWINTERING OF THE AECIOSPORES OF *CRONARTIUM RIBICOLA* FISHER

LOUISE DOSDALL

On April 19, 1918, a branch of white pine which had been killed by an heavy infection of white pine blister rust was found at Rush Lake, Minnesota. The branch contained many aecial scars in the cracks of which there were still numerous spores. It is very probable, if not indeed certain, that these were old aeciospores (1917) which had overwintered in the field. In the vicinity of Rush Lake the 1918 aecia were just breaking through the bark at this time and only in a few cases had the peridia broken. There was also no possibility of new aecia pushing through old scars on the particular specimen in question for the branch was quite dead. Hanging drop cultures were made of these hold-over aeciospores to determine whether they could have retained their viability. To avoid further possibility of obtaining 1918 spores which might have blown into the cracks the upper spores were scraped off and the spores for the cultures taken from the depths of the scars. Although the majority of the spores were badly desiccated, it was found that from one to two per cent germinated in sterile distilled water, each spore having from three to five germ tubes. As a further check, cultures were made of 1918 spores collected at the same place but it was found that under the same conditions these would not germinate. No other specimens of old spores could be found so that it was impossible to check this experiment by additional tests. The fact that the aeciospores produced in 1917 still germinated in the spring of 1918 indicates very clearly the possible overwintering of the rust by this method.

UNIVERSITY OF MINNESOTA, ST. PAUL.

REVIEWS

Winter Botany. By William Trelease, Professor of Botany in the University of Illinois. Published by the author, Urbana, Illinois, 1918. $2.50.

This companion volume to *Plant Materials of Decorative Gardening* by the same author is designed, as the title indicates, for use in identifying trees and shrubs when without foliage by means of their leaf-scar and bud differences. A brief introduction and the dichotomous keys occupy 40 pages followed by 360 pages of amply illustrated descriptions systematically arranged. Clear drawings assist the user on nearly every page. A few important references and a glossary and index occupy the remaining 34 pages. The volume is of convenient pocket size and should prove helpful to pathologists and inspectors in the identification of dormant hosts. The use of such a manual both in the field and on herbarium material promises to lead to greater accuracy in the mycologist's host index, since taxonomists report that a high percentage of the host plants of even type specimens of fungi are at present incorrectly identified.

H. A. Edson

PHYTOPATHOLOGICAL NOTES

Report alien property. The Alien Property Custodian requests that the attention of the readers of PHYTOPATHOLOGY be called to the provision of the "Trading with the enemy Act" which provides that all money or other property held by, for, or for the account of, or the benefit of, an enemy or ally of enemy, should be immediately reported to his office. This includes patents, trade-marks, copyrights, prints, labels, and designs. In connection with the last named, the following persons are required to make report:

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A circular of information defining "enemies" within the provisions of the "Trading with the enemy Act" can be secured upon application to the Alien Property Custodian, A. Mitchell Palmer, 16th and P Streets, N. W., Washington, D. C.

Field laboratories of the Pennsylvania Agricultural Experiment Station. In the spring of 1918 field laboratories for the investigation of plant diseases and insects were established by the Pennsylvania Agricultural Experiment Station at three localities in the State. These laboratories

are operated as branches of the main laboratories of the Experiment Station at State College. In each laboratory there has been located a plant pathologist and an entomologist. The authorities of the College and Experiment Station have considered this an important step in the solution of the many complex problems found in a state embracing such varied agricultural conditions. Investigators will have an opportunity to get into closer touch with the problems and the growers than is possible when all work is carried on at a central station. It is the intention to maintain trained investigators over a sufficient period to permit specialization upon certain major problems of a region. These laboratories are in a sense intermediate between ordinary field laboratories and substations. They are to be more permanent than the summer field laboratory, and yet differ from substations in being an integral part of the home laboratories as to policies and appropriations.

It is hoped that conditions may soon permit an extension of the idea. In locating the first three laboratories both agricultural and geographical considerations have entered into the plans. The locations are as follows: Arendtsville, Adams County, in the heart of a great apple growing belt; Bustleton, Philadelphia County, in the centre of a trucking region; and Girard, Erie County, where certain vegetables and small fruits are grown on a large scale. The pathologists located at these laboratories are Mr. R. C. Walton, formerly of the Ohio Agricultural Experiment Station, at Arendtsville; Dr. W. S. Beach, formerly of Illinois University, at Bustleton; and Mr. J. H. Muncie, formerly of the Plant Disease Survey Office, at Girard. Mr. Muncie replaces Mr. J. W. Miller, of the Pennsylvania State College, at Girard, Mr. Miller having resigned to enter into military service.

FRANK D. KERN

Personals. Mr. Fred C. Werkenthin has resigned his position as assistant professor of biology at the New Mexico College of Agriculture and Mechanic Arts to accept a position as associate professor of botany at the New Hampshire Agricultural College.

Dr. J. P. Bennett, formerly instructor in botany in the University of Wisconsin, has recently accepted the position of pathologist in potato disease investigations in the Bureau of Plant Industry.

Dr. Chas. T. Gregory, formerly assistant professor of plant pathology at Cornell University, has entered the Bureau of Plant Industry as extension pathologist in Truck and Forage Crop Diseases for the State of Indiana, with headquarters at Purdue University.

Miss Ruth Colvin of Indiana has been appointed scientific assistant in plant pathology, Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry.

Mr. W. H. Tisdale, formerly scientific assistant in cereal disease investigations, Bureau of Plant Industry, has become the head of the department of botany and plant pathology in the North Carolina College of Agriculture.

Mr. Wilber Brotherton, Jr., formerly instructor in botany in the University of Michigan, has entered the Bureau of Plant Industry to take up work on the breeding of disease-resistant peas.

Dr. Geo. M. Reed has resigned his position as professor of botany in the University of Missouri to take up work on the smuts of cereals as a pathologist of the Bureau of Plant Industry.

Mr. J. H. Muncie, formerly assistant in plant pathology at the Michigan Agricultural Experiment Station and recently pathologist with the Plant Disease Survey, Bureau of Plant Industry, has accepted the position of pathologist at the field laboratory of the Pennsylvania Agricultural Experiment Station at Girard, Pa.

Mr. G. Hamilton Martin, Jr., formerly instructor in botany at Washington State College, later a graduate student at Harvard University and assistant in plant pathology at the University of Washington, has recently been appointed plant pathologist with the Plant Disease Survey, Bureau of Plant Industry, Washington, D. C.

Mr. Morgan T. Binney, formerly assistant in the Department of Plant Pathology of the University of Wisconsin and a collaborator of the Bureau of Plant Industry in connection with barley disease investigations, has accepted a full time appointment in the Bureau as assistant pathologist, to take up work on root, stalk, and ear rots of corn.

Dr. James R. Holbert, who for a number of years has been agronomist in charge of corn improvement work for the Funk Brothers Seed Company, Bloomington, Ill., has become assistant pathologist in the Bureau of Plant Industry, engaged in corn disease investigations.

Dr. A. G. Johnson, associate professor of plant pathology at the University of Wisconsin, has accepted an appointment as pathologist in cereal disease investigations, Bureau of Plant Industry.

Mr. Allen G. Newhall, recently with the Plant Disease Survey, Bureau of Plant Industry, has been transferred to the Office of Cereal Investigations to assist in the barberry control campaign in Minnesota, in coöperation with the State Experiment Station.

LITERATURE ON PLANT DISEASES[1]

(September, 1918)

COMPILED BY EUNICE R. OBERLY, LIBRARIAN, BUREAU OF PLANT INDUSTRY, AND FLORENCE P. SMITH, ASSISTANT

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[1]This list includes references, both American and foreign, to the literature of plant pathology and mycology of interest to pathologists. Foreign references published since January 1, 1917, have been included beginning with the list appearing in v. 7. no. 3, June, 1917.

All authors are urged to cooperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. of Agric., Washington, D. C.

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[PHYTOPATHOLOGY for November (**8**: 557–587, Pl. IV) was issued November 21, 1918.]

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